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A Study on Biogas: Utilization of Energy Resources

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ABSTRACT: This review is a summary of different aspects of the bio.gas production. Biogas is a value-added product of anaerobic digestion of organic compounds. Biogas production depends on different factors including: pH, temperature, substrate, loading rate, hydraulic retention time (HRT), C/N ratio, and mixing. Biogas and fertilizer obtained at the end of anaerobic digestion could be used for cooking, lighting, and electricity.

KEYWORDS: Energy development; Biogas; Digester; Gas-holders; Substrates; Sludge management; Manure; Scum; Biometahanation; Eutrophication; Moisture.

I. INTRODUCTION

Due to the increasing prices of fossil fuels and taxes on energy sources, finding alternative, clean and economical sources of energy has nowadays become a major concern for households and nation's economies. Energy demand is a critical reason for extensive climate change, resource exploitation, and also restricts the living standards of humans. By the time fuel and fertilizer reaches rural areas, the end price is relatively expensive due to high transport costs, leaving people to find alternative resources other than oil. Many of the rural communities in developing countries are forced to rely on the traditional energy sources such as firewood, dung, crop residues, and paraffin. These traditional methods are often expensive and/or time-consuming. Cooking accounts for 90% of energy consumption in the households of developing countries. The application for rural and urban waste biogas production is widely spread. This review deals with a summary of different biogas digesters, their operating parameters, cost and materials used to build them, start-up, and maintenance, the variety of applications employed, and associated social and environmental effects.

II. RESEARCH TASK

Technical field of invention

In a first aspect, the present invention concerns an anaerobic digestion of animal manures, energy crops and similar organic substrates. The process is capable of refining nutrients comprised in the digested biomass to fertilizers of commercial quality.

One additional aspect of the invention is the possible application for disposing of animal waste in the form of animal carcasses, slaughterhouse waste, meat and bone meal, etc. The waste is refined in the plant to fertilizers to be applied to agricultural land. The animal produce is in this concept not used as fodder but fertilizer. The destruction of possible biomass treated in the plant in combination with the use of the refined biomass as fertilizer instead of fodder substantially radices if not eliminates the risk of infecting animals or humans.

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Biogas

Biogas, the metabolic product of anaerobic digestion, is a mixture of methane and carbon dioxide with small quantities of other gases such as hydrogen sulphide. Methane, the desired component of biogas, is a colourless, blue burning gas used for cooking, heating, and lighting. Biogas is a clean, efficient, and renewable source of energy, which can be used as a substitute for other fuels in order to save energy in rural areas. In anaerobic digestion, organic materials are degraded by bacteria, in the absence of oxygen, converting it into a methane and carbon dioxide mixture. The digestate or slurry from the digester is rich in ammonium and other nutrients used as an organic fertilizer.

History of Biogas plant

A biogas plant is an anaerobic digester that produces bio-gas from animal waste or energy crops. Energy crops are cheap crops grown for the purpose of bio fuels, rather than food.

Construction of bio gas plant depends upon:

- Amount of gas needed
- Amount of waste
- Type of digester

Biogas is primarily methane and carbon dioxide (CO₂) and may have small amounts of hydrogen sulphide, moisture and siloxanes. The gases methane, hydrogen, and carbon monoxide (CO) can be combusted or oxidized with oxygen. This energy release allows biogas to be used as a fuel; it can be used for any heating purpose, such as cooking. It can also be used in a gas engine to convert the energy in the gas into electricity and heat.

Biogas is produced as landfill gas (LFG), which is produced by the breakdown of Biodegradable waste inside a landfill due to chemical reactions and microbes, or as digested gas, produced inside an anaerobic digester.

III. DESIGN

Throughout the world, a countless number of designs of biogas plants have been developed under specific climatic and socio-economic conditions. Choosing a design is essentially part of the planning process. It is, however, important to familiarize with basic design considerations before the actual planning process begins. This refers to the planning of a single biogas unit as well as to the planning of biogas-programs with a regional scope. The performance of a biogas plant is dependent on the local conditions in terms of climate, soil conditions, the substrate for digestion and building material availability. The design must respond to these conditions. In areas with generally low temperatures, insulation and heating devices may be important. If bedrock occurs frequently, the design must avoid deep excavation work. The amount and type of substrate to be digested have a bearing on size and design of the digester and the inlet and outlet construction. The choice of design will also be based on the building materials which are available reliably and at reasonable cost.

Types of plants

There are various types of plants. Concerning the feed method, three different forms can be distinguished:

- Batch plants
- Continuous plants
- Semi-batch plants

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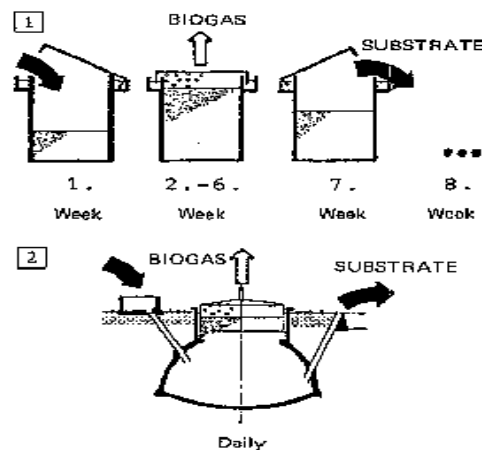


Fig. 1 Feed methods

Working of a biogas plant

The feed material is mixed with water in the influent collecting tank. The fermentation slurry flows through the inlet into the digester. The bacteria from the fermentation slurry are intended to produce biogas in the digester. For this purpose, they need time. Time to multiply and to spread throughout the slurry. The digester must be designed in a way that only fully digested slurry

can leave it. The bacteria are distributed in the slurry by stirring (with a stick or stirring facilities). The fully digested slurry leaves the digester through the outlet into the slurry storage.

The biogas is collected and stored until the time of consumption in the gasholder. The gas pipe carries the biogas to the place where it is consumed by gas appliances. Condensation collecting in the gas pipe is removed by a water trap.

Depending on the available building material and type of plant under construction, different variants of the individual components are possible. The following (optional) components of a biogas plant can also play an important role and are described separately: Heating systems, pumps, weak ring.

Construction details

The section on construction of biogas plants provides more information on:

- Agitation
- Heating
- Piping systems
- Plasters and Coats
- Pumps
- Slurry equipments
- Underground Water.

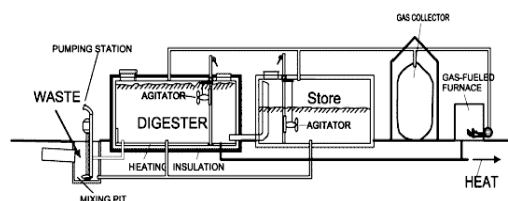


Fig. 2 Construction Parts in Biogas plant

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IV. PARTS OF BIOGAS PLANT

Influent collecting tank

Fresh substrate is usually gathered in an influent collecting tank prior to being fed into the digester. Depending on the type of system, the tank should hold one to two days substrate. An influent collecting tank can also be used to homogenize the various substrates and to set up the required consistency, e.g. by adding water to dilute the mixture of vegetable solids (straw, grass, etc.), or by adding more solids in order to increase the biomass.

Inlet and outlet

The inlet (feed) and outlet (discharge) pipes lead straight into the digester at a steep angle. For liquid substrate, the pipe diameter should be 10-15 cm, while fibrous substrate requires a diameter of 20-30 cm. The inlet and the outlet pipe mostly consist of plastic or concrete.

Both the inlet and the outlet pipe must be freely accessible and straight, so that a rod can be pushed through to eliminate obstructions and agitate the digester contents. The pipes should penetrate the digester wall at a point below the lowest slurry level (i.e. not through the gas storage). The points of penetration should be sealed and reinforced with mortar.

Digester

Requirements: No matter which design is chosen, the digester (fermentation tank) must meet the following requirements:

1. Water/gas tightness
2. Insulation
3. Structural stability
4. Internal and external forces
5. Shapes of digesters

Gasholders

Basically, there are different designs of construction for gasholders used in simple biogas plants:

- Floating-drum gasholders
- Fixed-domes gasholders
- Plastic gasholders
- Separate gasholders

1. Floating-drum gasholders: Most floating-drum gas-holders are made of 2-4 mm thick sheet steel, with the sides made of thicker material than the top in order to compensate for the higher degree of corrosive attack. Structural stability is provided by L-bar bracing that also serves to break up surface scum when the drum is rotated. A guide frame stabilizes the gas drum and prevents it from tilting and rubbing against the masonry. The two equally suitable and most frequently used types are:

An internal rod & pipe guide with a fixed (concrete-embedded) cross pole (an advantageous configuration in connection with an internal gas outlet). External guide frame supported on three wooden or steel legs.

All grades of steel normally used for gas-holders are susceptible to moisture-induced rusting both in- and outside. Consequently, a long service life requires proper surface protection, including:

- Thorough de-rusting and de-soiling
- Primer coat of minimum 2 layers
- 2 or 3 cover coats of plastic or bituminous paint.

2. Fixed-dome gasholders: A fixed-dome gas-holder can be either the upper part of a hemispherical digester (CAMARTEC design) or a conical top of a cylindrical digester (e.g. Chinese fixed-dome plant). In a fixed-dome plant the gas collecting in the upper part of the dome displaces a corresponding volume of digested slurry.

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An overflow into and out of the compensation tank must be provided to avoid overflowing of the plant. The gas outlet must be located about 10 cm higher than the overflow level to avoid plugging up of the gas pipe.

A gas pressure of 1 m WC or more can develop inside the gas space. Consequently, the plant must be covered sufficiently with soil to provide an adequate counter pressure. Special care must be taken to properly close the man hole, which may require weighing down the lid with 100 kg or more.

3. Plastic gas-holders: Gas-holders made of plastic sheeting serve as integrated gas-holders, as separate balloon/bag-type gas-holders and as integrated gas-transport/storage elements. For plastic (sheet) gas-holders, the structural details are of less immediate interest than the question of which materials can be used.

4. Separate gas-holders: Differentiation is made between- Low-pressure, wet and dry gas-holders (10-50 mbar). Basically, these gas-holders are identical to integrated and/or plastic (sheet) gas-holders. Separate gas-holders cost more and are only worthwhile in case of substantial distances (at least 50-100 m) or to allow repair of a leaky fixed-dome plant. This type of separate gas-holder is also used to buffer extreme differences between gas-production and gas-use patterns. Medium- or high-pressure gas-holders (8-10 bar / 200 bar)

Gas pipe, valves and accessories

Biogas piping: At least 60% of all non-functional biogas units are attributable to defect gas piping. Utmost care has to be taken, therefore, for proper installation. For the sake of standardization, it is advisable to select a single size for all pipes, valves and accessories. The requirements for biogas piping, valves and accessories are essentially the same as for other gas installations. However, biogas is 100% saturated with water vapour and contains hydrogen-sulphide. Consequently, no piping, valves or accessories that contain any amounts of ferrous metals may be used for biogas piping, because they would be destroyed by corrosion within a short time. The gas lines may consist of standard galvanized steel pipes. Also suitable (and inexpensive) is plastic tubing made of rigid PVC or rigid PE. Flexible gas pipes laid in the open must be UV-resistant.

When installing a gas pipe, special attention must be paid to:

- Gas-tight, friction-type joints
- Line drainage, i.e. with a water trap at the lowest point of the sloping pipe in order to empty water accumulation
- Protection against mechanical impact.

Heating systems

Normally, because of the rather high involved costs, small-scale biogas plants are built without heating systems. But even for small scale plants, it is of advantage for the biomethanation process to warm up the influent substrate to its proper process temperature before it is fed into the digester. In principle, one can differentiate between:

- Direct heating in the form of steam or hot water, and
- Indirect heating via heat exchanger, whereby the heating medium, usually hot water, imparts heat while not mixing with the substrate.

Pumps

Pumps become necessary parts of a biogas unit, when the amounts of substrate require fast movement and when gravity cannot be used for reasons of topography or substrate characteristics. Pumps transport the substrate from the point of delivery through all the stages of fermentation. Therefore, several pumps and types of pumps may be needed. Pumps are usually found in large scale biogas units.

Types of pump: There are two predominant types of pump for fresh substrate- Centrifugal pumps & Positive-displacement pumps (reciprocating pumps). Centrifugal pumps operate on the principle of a rapidly rotating impeller located in the liquid flow. They provide high delivery rates and are very robust, i.e. the internals are exposed too little mechanical stress. They do, however, require a free-flowing intake arrangement, because they are not self-priming (regenerative).

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Pump delivery lines: Pump delivery lines can be made of steel, PVC (rigid) or PE (rigid or flexible), as well as appropriate flexible pressure tubing made of reinforced plastic or rubber. Solid substrate, e.g. dung, can also be handled via conveyor belt, worm conveyor or sliding-bar system, though none of these could be used for liquid manure. When liquid manure is conducted through an open gutter, small weirs or barrages should be installed at intervals of 20-30 m as a means of breaking up the scum layer.

V. SUBSTRATE TYPES & MANAGEMENT

Cattle dung and manure

Cattle dung is the most suitable material for biogas plants because of the methane producing bacteria already contained in the stomach of ruminants. The specific gas production, however, is lower and the proportion of methane is around 65% because of prefermentation in the stomach. Its homogenous consistency is favourable for use in continuous plants as long as it is mixed with equal quantities of water. Fresh cattle dung is usually collected and carried to the system in buckets or baskets. Upon arrival it is hand-mixed with about an equal amount of water before being fed into the digester. Straw and leftover fodder or hay is removed by hand in order to prevent clogging and reduce scum formation. Since most simple cow-sheds have dirt floors, the urine is usually not collected. When it is, it usually runs along the manure gutter and into a pail standing in a recess at the end of the gutter.

Liquid cattle manure, a mixture of dung and urine, requires no extra water. However, the simple animal housing found on most farms in developing countries normally does not allow the collection of all animal excrement. Hence, most of the urine with its valuable plant nutrients is lost.

VI. BIOGAS - SLUDGE MANAGEMENT

Sludge storage

To retain the maximum fertilizing quality of digested slurry, i.e. its nitrogen content, it should be stored only briefly in liquid form in a closed pit or tank and then applied on the fields. Preferably, it should be dug into the soil to prevent losses on the field.

Sludge storage is normally affected according to one or the other of the following three techniques:

- Liquid storage
- Drying
- Composting

Composition of sludge

Process of biomethanation: Anaerobic digestion draws carbon, hydrogen and oxygen from the substrate. The essential plant nutrients (N, P, K) remain largely in the slurry. The composition of fertilizing agents in digested slurry depends on the fermented substrate and can, therefore, vary within certain limits. For an average daily substrate feed rate of 50 kg per livestock unit (LSU = 500 kg live weight) and a daily gas yield of 1 m³ biogas/LSU, the mass of the influent substrate will be reduced by some 2% through the process of bio-methanation (volumetric weight of biogas: 1.2 kg/m³).

VII. BIOGAS UTILIZATION

Gas production

If the daily amount of available dung (fresh weight) is known, gas production per day in warm tropical countries will approximately correspond to the following values:

- 1 kg cattle dung 40 litres biogas
- 1 kg buffalo dung 30 litres biogas
- 1 kg pig dung 60 litres biogas
- 1 kg chicken droppings 70 litres biogas

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Efficiency

The calorific efficiency of using biogas is 55% in stoves, 24% in engines, but only 3% in lamps. A biogas lamp is only half as efficient as a kerosene lamp. The most efficient way of using biogas is in a heat-power combination where 88% efficiency can be reached.

Table 1 Comparisons of calorific efficiency

Appliances	gas lamps	Engines	Engines	power-heat
efficiency [%]	3	24	55	88

For the utilization of biogas, the following consumption rates in litres per hour (l/h) can be assumed:

- Household burners: 200-450 l/h
- Industrial burners: 1000-3000 l/h
- Refrigerator (100 l) depending on outside temperature: 30-75 l/h
- Gas lamp, equiv. to 60 W bulb: 120-150 l/h
- Biogas / diesel engine per bhp: 420 l/h
- Generation of 1 kWh of electricity with biogas/diesel mixture: 700 l/h
- Plastics moulding press (15 g, 100 units) with biogas/diesel mixture: 140 l/h

Gas demand

As a rule of thumb, the cooking energy demand is higher for well-to-do families than for poor families. Energy demand is also a function of the energy price. Expensive or scarce energy is used more carefully than energy that is effluent and free of charge. The gas consumption for cooking per person lies between 300 and 900 litre per day, the gas consumption per 5-member family for 2 cooked meals between 1500 and 2400 litre per day.

VIII. CONCLUSION

Access to energy resources, economic development and environmental pollution, which in turn threatens human health, is major challenges facing developing countries today. Economically feasible and efficient small scale biogas digesters could be the answer of solving some of these problems and needs. By enhancing energy availability and simultaneously protect the surrounding environment such as soil, water and air, a lots of benefits could be gained. More or less, every biodegradable organic waste can be treated in a biogas digester, providing energy for cooking, lighting and heating along with increased of dissolved nutrient concentration in the digestate. Thus, providing farmers with an improved organic fertilizer. It seems the benefit from implementation of biogas digester alone is not enough to increase the attention. Further, full analysis are needed with a new approach to facilitate communication between the experts from different fields such as engineering, hydrology, biology, social science, economics and systems-modelling to identify and find the best possible optimum solution and strategies needed in implementing household biogas in rural communities.

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